Developing an LED Light Source for Flatfield Imaging and Instrument Calibration

Lionel Elkins
Consortium for Undergraduate Research Experience
East Los Angeles College
Monterey Park, California
elkins_lionel@yahoo.com

Dr. Neil Murphy
California Institute of Technology
Jet Propulsion Laboratory
Pasadena, California
neil.murphy@jpl.nasa.gov

***Abstract*—In order to make use of data taken of Jupiter at the Lick Observatory in April 2017, proper flat field images were needed. Development began of an in-lab LED light source that could be used to gather the necessary flat field data and be used to calibrate the imaging instrument. This light source was designed to replicate the incoming light from the Shane 3-meter cassegrain telescope at Lick Observatory. This was accomplished by using various optomechanical components and prescription lenses found using computer simulation programs.**

***Index Terms* – Planetary Doppler Imager, LED, Optics, Optomechanics, Flat Field**

I. Introduction

In 2016, interns at the Jet Propulsion Laboratory developed an instrument to study the interior structure of our solar systems giant planets using doppler imaging. Jupiter and Saturn, the gas giants, are composed primarily of hydrogen, making them similar in composition to our sun. Using similar techniques developed for helioseismology, the interiors of these planets can be probed by observing their resonant oscillations. These observations can be made by imaging the Doppler shifts at the surface of the planet caused by these oscillations. The Planetary Doppler Imager is a ground based instrument that utilizes magneto-optical filters and only allows light to pass in two narrow pass-bands. In April 2017, the Planetary Doppler Imager was taken to the Shane 3-meter telescope at the Lick Observatory on Mount Hamilton for 10 nights to image Jupiter. Unfortunately, the flat field data that was gathered during that time proved insufficient to be used to reduce the data collected. To achieve the desired flat field data, it was proposed that a benchtop LED light source be designed to replicate the incoming light from the Shane 3 meter telescope. This light source could be used in lab to collect flat field data and also be used for calibrating the instrument.

II. Theory

Building a benchtop light source to replicate the incoming light from the Shane telescope would allow flat field images to be taken in lab. Since the light emitted by this source can be made to be sufficiently flat, any unknown structure in the images due to issues with the instrument can be identified and fixed. Once the flat field data is taken, further calibrations on the instrument can be made, optimizing it for the Shane telescope and the next observing run.

III. Optical Design

The optical design for the light source was done using Zemax OpticStudio. To replicate the incoming light from the telescope, the convergence angle of ~1.7° (all convergence and divergence angles are given in half-angle) and an image size of 18.0mm at the primary focus had to be achieved using optical components from ThorLabs, Inc. Since the instrument only takes in light at 770nm, the M780D2 LED chip was the ideal choice (Figure 1). An AC254-050-B achromatic doublet lens was used to collimate the light from the LED before passing through the diffuser. To achieve the final image size, an ID25 Iris was placed just before the DG10-1500 Ground Glass Diffuser to create a 7.2mm diameter aperture. The LED, achromatic doublet lens, iris, and diffuser made up the first part of the optical design (Figure 1).

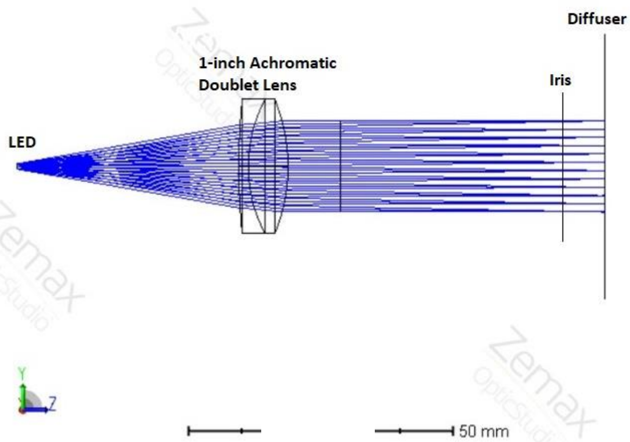

Figure 1

The second part of the optical design consisted of the diffuser, a meniscus lens, two plano-convex lenses, and the

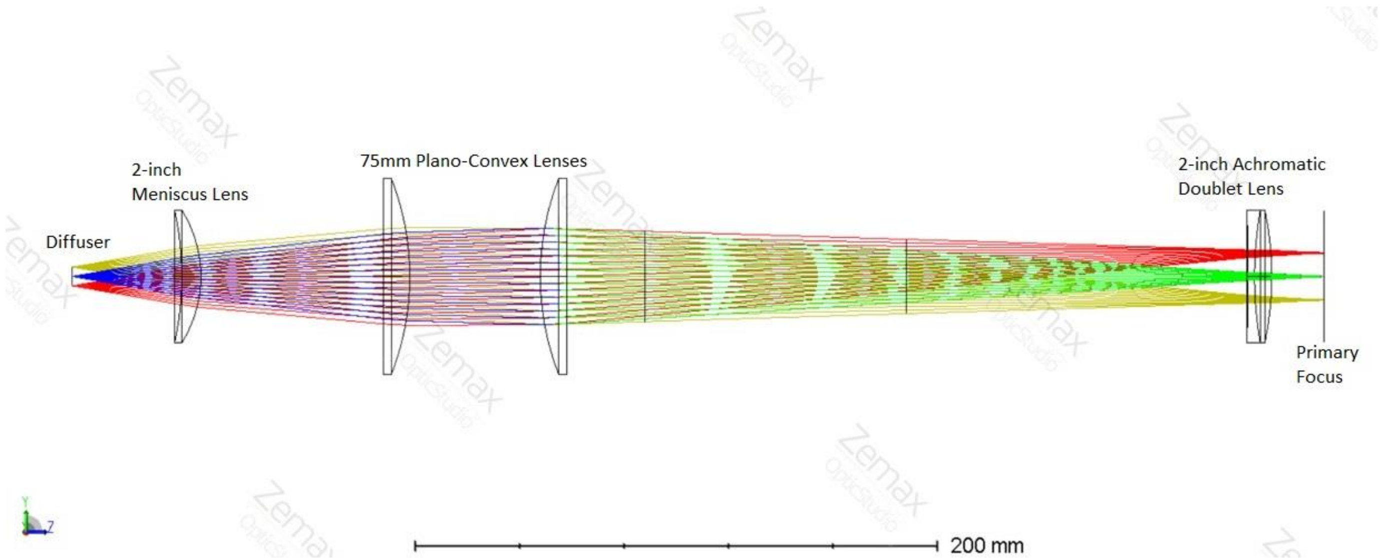

Figure 2

achromatic doublet lens at the instruments primary aperture (Figure 2). Starting from the diffuser, with a 20° divergence angle, an LE1418 Positive Meniscus Lens was placed at 42.0mm followed by an LA1353 Plano-Convex Lens at 119.3mm and then another plano-convex lens at 179.4mm. This arrangement achieved a convergence angle of 1.77°. Placing the last surface of the plano-convex lens 260.9mm from the achromatic doublet on the instrument produced an image size of 18.18mm.

IV. Mechanical Design

The design process consisted of the optical design and the mechanical design being done simultaneously. Though there were parts of the mechanical design that hinged on the completion of the optical design, many aspects of the former could be accomplished independently. The initial mechanical design consisted of the LED, a diffuser, and mounts for everything including lenses. Also, independent of the optical design was the design of the LED circuit and thermal management options. The CAD software Fusion 360 was used for most of the 3D design.

Sufficient cooling would be needed for the LED to operate properly. The ATSEU-077B-C3-R0 Star LED Heatsink by Advanced Thermal Solutions, Inc. was selected because of its size (Figure 3). Using a 3D printed model of this heatsink, the housing and mount for the LED was designed. To regulate the current to the LED, the 3021-D-I-700 BuckPuck LED Driver was used (Figure 4). This current regulating driver allowed the current drawn by the LED to be regulated and tuned between 0mA – 700mA. This component would be soldered onto a small circuit board and wire leads attached.

Figure 4: Heat Sink

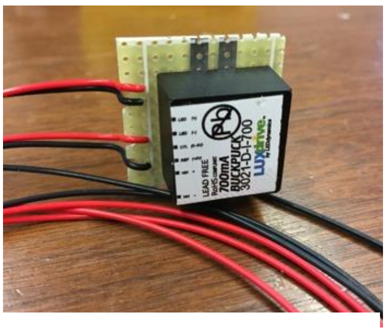

Figure 3: LED Driver with wire leads

The housing and mount were designed around this build. Various mounts were constructed using the 3D printed parts. The final product was a pair of clamps, one ring shaped with small extrusions to hold the back of the heatsink and one ventilated flat surface with a hole for the front. This would be inserted into an LCP01T 60mm Cage Plate and clamped together with retaining rings meant to hold optical components in place (Figure 5). A small box and lid were 3D printed to house the small circuit board and attach to the 60mm cage system (Figure 6).

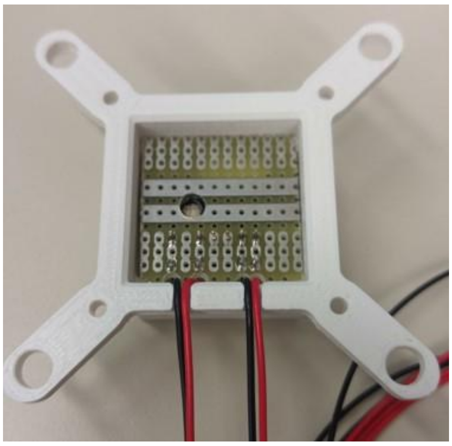

Figure 5: 3D printed housing with Driver circuit

Figure 6: LED/Heatsink Assembly

The LED mount, along with all the other mounts, attached to a 66mm Single Dovetail Rail which would be fixed to the top surface of the work bench. Most of the components fit easily on clamps attached to posts and post holders (Figure 7). Difficulty arose with the 75mm plano-convex lenses. The lenses needed to be adjustable in the X and Y directions orthogonal to the optical axis, which is fixed by the instrument at 146mm from the top surface of the work bench. Precision XY Translation Mounts were available for the 1- and 2-inch lenses but not for the 75mm lenses. A possible solution for this issue is vertically translating optical posts and linear translation stages.

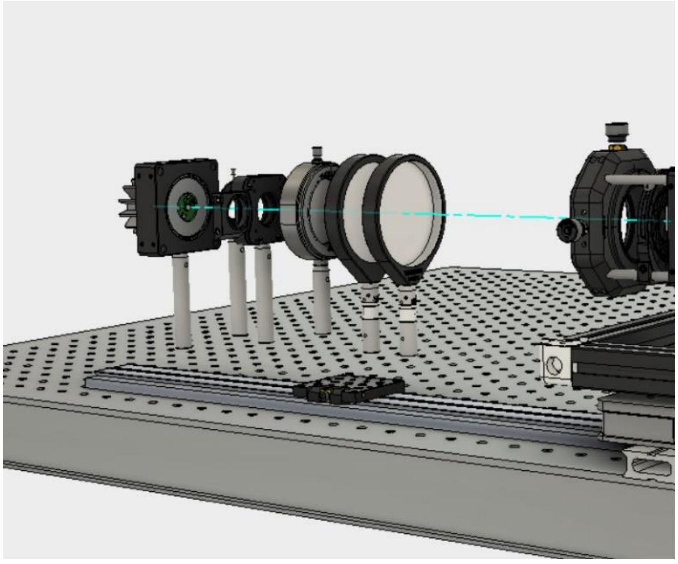

Figure 7: Incomplete Assembly on Benchtop

Unfortunately, the rest of the mechanical design could not be completed until the optical design was finished. This took longer than expected due to the complexity of the optics.

V. Next Steps

Once the optical design is finalized, the mechanical design can be completed and the whole thing assembled and aligned. The LED chip is not yet connected to the driver circuit or power supply. This needs to be done so the LED power output can be tested. Since the LED emits in infrared, adding a small colored indicator LED in series will indicate when the LED is in operation. Another safety and utility feature that would make a great addition to the circuit is an on-off switch. This would allow easy operation. Once the LED has been tested and the optics aligned, the imager will be used to capture flat field images and the data collected on the last observing run can be reduced. Then using this device, the instrument can be calibrated and improved before the next observing runs for Jupiter and Saturn in 2018.

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